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## Equity dimensions of micro-generation: A whole systems approach

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## Equity dimensions of micro-generation: A whole systems approach

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Micro-generation represents one technology ready option for making the low carbon transition. Energy choices we make in the present have implications for future generations. Existing methods for formulating energy policy and assessing the suitability of micro-generation technology often concentrate upon a subset of issues relating to specific economic criteria or policy targets or on one technology, but often fail to adopt a whole systems approach or consider present or future equity issues. Important factors are often overlooked leading to poorly implemented policy or unsatisfactory technology deployment. There is a clear need for a process or assessment methodology that focuses upon equity while making choices relating to micro or small-scale generation projects. This paper describes an integrated whole systems methodology developed heuristically by a wide range of interdisciplinary stakeholders for use by groups of decision makers when assessing the equity aspects of micro-generation projects. The paper discusses the desirable attributes that this type of assessment should have and outlines the merits of the whole systems approach. Steps taken to develop, test, and refine the methodology using case studies are discussed. The equity issues arising from each case study are examined in wider context by quantifying the impact micro or small-scale generation could have within English households of varying age and tenure in a range of settings including a real community case study. This provides a snapshot of where equity issues manifest themselves and considers the numbers of households they affect. Using the methodology and focusing upon equity has allowed recommendations to be made that could inform future energy policy.

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### I. INTRODUCTION

Provisional 2010 figures for the UK indicate that around 17% of UK carbon dioxide emissions are produced by the domestic sector<sup>1</sup> and it is anticipated that domestic micro-generation systems could produce enough renewable energy to reduce household carbon emissions by 15% per annum by 2050.<sup>2</sup> The UK has set ambitious targets for new housing to be zero carbon by 2016 (Ref. 3) and the UK Energy White Paper<sup>4</sup> highlights the important role anticipated for micro or small-scale generation for future energy provision. Evidence suggests that future uptake of micro-generation technology in the UK will increase<sup>5</sup> and the Energy Saving Trust has estimated that micro-generation alone could meet 30%–40% of the UK's electricity requirements by 2050.<sup>6</sup> This will require the transformation of the UK electricity system from a highly centralised fossil fuel based system to one where generation is distributed among consumers who own and operate either individual or shared generation systems within their communities.

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This paper makes reference to both micro and small-scale distributed generation systems used in communities. Using the definition of Ackermann *et al.*,<sup>7</sup> micro-generation systems occupy the range 1 W to 5 kW and small-scale generation systems range from 5 kW to 5 MW. For the purposes of this study, communities are defined as groups of people who may or may not know each other but who share certain housing tenure and energy related characteristics. Examples include groups of like minded people actively working together to develop local energy projects, an island community or a group of people who are living in a particular type of housing operated by a registered social landlord (RSL) where micro or small-scale generation has been installed.

The potential for micro-generation to increasingly contribute to climate change mitigation is recognised by policy makers as signalled by the recent introduction of interventions such as Feed in Tariffs (FiTs). This general approval does not, however, obscure the need among those who intend to deploy micro or small-scale generation for a full and careful scrutiny of how its costs and benefits might be unevenly dispersed. A review of existing literature shows that assessments of micro and small-scale generation systems by social housing providers, local authorities, landlords, businesses, public sector institutions and community energy projects are often made using one particular approach e.g., life cycle analysis (lca), cost benefit analysis (cba), or multi criteria decision analysis (mcda).<sup>8</sup> Assessments may be directed towards one particular generation technology<sup>9-11</sup> or one particular setting.<sup>12</sup> Those that do employ a range of assessment tools often assign a numerical weighting or ratio to their outputs.<sup>8,13</sup> While these approaches are necessary to map against targets, or make an economic case for or against technology adoption, when examining the role of micro and small-scale generation within the context of equity, they are too often insufficient. The authors propose that full and careful assessment of the suitability of micro and small-scale generation schemes requires a tool that supports equitable decision making that can be undertaken collaboratively both within and between organisations and representatives of groups that are most affected.

As part of the work of **Interdisciplinary Cluster on Energy Systems Equity and Vulnerability (InCluESEV)**, a methodology was developed to suit this purpose in close co-operation with a range of energy and housing stakeholders who developed and subsequently tested its effectiveness. The methodology presented here is not restricted to any one form of generation as it could be used to assist in decisions about which technologies might be most suited to particular locations and circumstances; just as readily it can be used to address questions concerning a favoured technology. As a whole systems approach, it is capable of being used to gain an overarching view of propositions concerning micro-generation, but was developed in the specific context of concerns for achieving equity. In the workshops where the methodology was created and refined, participants were asked to give special consideration to the impact of micro-generation on issues of environmental justice in terms of both distributive justice (the distribution of good and bad effects) and procedural justice (the means by which equitable outcomes can be achieved). However, discussion most frequently came to rest on the former and more work may be needed to capture procedural aspects of equity in decision making around micro and small-scale generation. The intention was to produce an interdisciplinary methodology that reflected and satisfied the interests of workshop participants who came from a wide range of energy and housing related academic and non-academic backgrounds that could then be applied to a wide range of community energy projects.

The process of producing the Whole Systems methodology included:

- (i) A literature review to identify the need for an equity focused whole-systems assessment methodology and to help define research questions and examine the attributes and limitations of existing assessment methods.
- (ii) A stakeholder mapping event attended by a broad range of stakeholders with the aim of identifying and populating research questions and developing the methodology by collectively assessing desirable attributes.
- (iii) A whole systems SWOT analysis (strengths, opportunities, weaknesses, and threats) undertaken by stakeholders to examine the issues surrounding micro-generation with the aim of promoting wider whole-systems thinking and highlighting equity issues.

- (iv) A workshop attended by stakeholders to test and further refine the methodology and suggest future related research opportunities.

The outcome of these activities is a heuristic integrated whole-systems methodology accessible for participants in all disciplines, which uses an iterative structure that prompts decision makers to promote mutual compromise by discussing the equity implications of proposed energy projects amongst an interdisciplinary team of decision makers. The methodology was initially tested and refined using imaginary case studies developed by the project team that were used as thought experiments. Subsequently, the methodology was further tested using a real case study from the UK. Testing has provided useful information about the relative importance of variables used within the methodology. Research findings could be used to inform energy policies that focus upon the social and environmental benefits and disadvantages of micro and small-scale generation. The authors envisage that the methodology will be of particular use to the mix of people and organisations that took part in its creation, especially housing associations, commercial landlords, consultants, and energy “intermediaries,” providers of micro and small-scale generation systems, local authority departments, community energy projects, residents’, and business associations.

## II. ENERGY EQUITY AND MICRO-GENERATION

Equity is closely linked with aspects of environmental justice which has both distributive and procedural dimensions.<sup>14</sup> These two concepts are discussed and mapped by Ikeme.<sup>15</sup> The distributive element of environmental justice is what is normally encompassed by the term equity and essentially relates to the good and bad consequences of social exchanges between different groups of people.<sup>16</sup> Informed by the work of Ikeme,<sup>15</sup> the equity aspects associated with micro-generation technology can be simply described in terms of the distribution of impacts, distribution of responsibility and distribution of costs and benefits associated with its uptake.

The distribution of impacts is demonstrated by the effects of climate change. Developed nations are responsible for most emissions while developing nations suffer the worst consequences of climate change through flooding or drought.<sup>17,18</sup> One example of the distribution of impacts for a micro-generation system could be a micro-generator installed on one home in a community causing problems (e.g., noise, interference or visual impact) for a neighbouring property.

Distribution of responsibility can be illustrated by countries that are least threatened by the effects of climate change. These countries are generally developed nations that have the wealth, technical know-how and capacity to mitigate the impacts of climate change using technology interventions (e.g., carbon capture and storage or by generating energy from low carbon sources<sup>15</sup>) and social interventions (e.g., by promoting behavioural change and good energy citizenship to reduce their energy demands). However, should these countries have a responsibility to do so? For example in the UK, micro-generation systems could be made mandatory on all new homes by amending building regulations and excessive consumption could be curbed with information on the benefits of saving energy and introducing penalties for higher energy users (while appreciating that high energy demands are not always associated with the user and may be more related to building fabric or the type of energy provision installed).

Distribution of costs and benefits can be demonstrated by the uptake of micro-generation systems. Early adopters pay a higher price for installing micro-generation because markets are less well developed, this is partly addressed through policy instruments such as FiTs and early adopters will benefit from higher FiTs. More universally, installing micro-generation can benefit everyone by reducing total carbon emissions.

## III. THE InCluESEV APPROACH

The InCluESEV is an interdisciplinary research cluster comprising a core of 30 academics from across 13 disciplines. Wider dimensions of time and space are often not considered when planning micro and small-scale generation projects. There may be little awareness of the equity

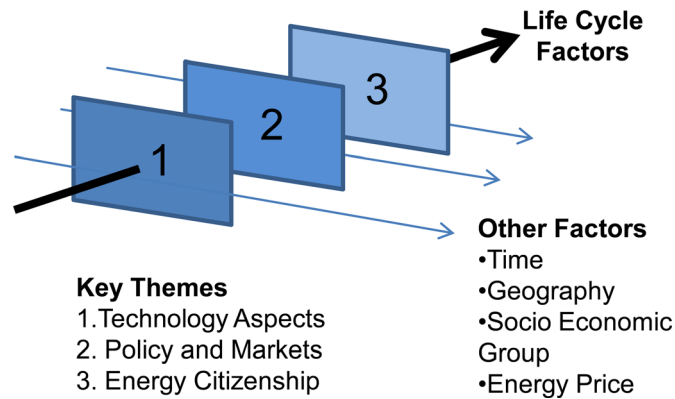


FIG. 1. Schematic representation of the whole systems approach and cross-cutting themes.

dimensions of energy technologies at whole systems level, i.e., there is no basis upon which to judge equity implications. The InCluESEV project advocates a “whole systems” approach whereby equity implications are considered across the whole lifecycle of the technology, i.e., from manufacture to decommissioning.

The aim of this research (undertaken as part of one of the work packages supported by InCluESEV) is to develop a whole systems methodology for assessing micro-generation projects that considers three key areas alongside unforeseen, uncertain, and variable factors, such as time, geography, socio economic group and energy price, while maintaining a focus upon equity and carbon (Figure 1). The three areas were defined by the overarching aims of InCluESEV and are concurrent with those used in parallel work packages focusing upon nuclear energy and carbon capture and storage to allow future comparison between each low carbon technology option. The three areas are:

- (i) The technological aspects of micro-generation
- (ii) The policy and markets issues relating to micro-generation
- (iii) The social issues related to the uptake of micro-generation

This methodology was developed by the interdisciplinary team of stakeholders described above, which consisted of representatives from academia (physical and social sciences), fuel poverty charities, social enterprises, housing associations, technology manufacturers, electricity distribution network operators, energy researchers, electricity generators, education and training providers, energy supply companies, power systems consultants and The Energy Saving Trust. The stakeholders also provided insights from the viewpoint of their customers and the communities they interact with. The integrated whole systems methodology resulting from this process has been subjected to testing, revision, and improvement by users from different disciplines and draws upon many combined years of energy related industrial and academic experience.

Engaging a wide range of stakeholders is an approach advocated by Madlener *et al.*<sup>19</sup> who developed a whole systems assessment methodology as part of the ARTEMIS project which aimed to develop future renewable energy scenarios for Austria. Their methodology combines scenario development, multi-criteria evaluation and stakeholder input but provides a numerical output.

#### IV. THE WHOLE SYSTEMS APPROACH

A whole systems approach was supported by the stakeholder group because of the disadvantages previously highlighted with respect to existing assessment methods and the fact that they can be too rigid to accommodate unknown factors, e.g., new and developing technologies and frequent changes in energy policy and pricing. Stakeholders also agreed that methods that weight the variables,<sup>8,20</sup> and result in a numerical output, may deter certain users because they may not have access to or understand any required numerical input data, may disagree on assigning



weightings and because they may not effectively capture feelings on specific social issues, e.g., risk and trust. Another major disadvantage of these assessment methods is the failure to include other important factors such as socio-political aspects and stakeholder preferences.<sup>21</sup>

A whole systems perspective adopts a holistic approach to whatever is being studied by identifying the various elements of systems and sub-systems and focusing enquiry on the interactions that take place between them. It is a method of enquiry that seeks to interpret the dynamic qualities of complex phenomenon and identify and potentially forestall, problems arising from unintended and unforeseen consequences. By its very nature, whole systems is interdisciplinary because no one specialisation can suffice to understand a concatenation of effects.

When applied to micro-generation, a whole systems approach involves specifying a selected technology, such as a wind turbine or photovoltaic installation, and assessing the implications for its deployment at particular locations and among a range of users who ideally are involved in the process. The methodology developed from the InCluESEV project invites decision makers and stakeholders to work in groups to identify the various elements of a proposal, and to concentrate on understanding the dynamics that exist between them. The methodology acts as a mechanism to enable deliberative and collaborative decision making by providing a framework that prioritises interactions between constituent parts of the complex whole. This emphasis on detecting linkages and potential knock on effects is designed to reveal hidden problems and direct attention to unintended consequences. The overall aim of the methodology is to ensure that micro-generation has optimal outcomes for technical efficiency, to encourage citizen engagement,<sup>22</sup> and to facilitate projects where costs and benefits are scrupulously examined from an equity perspective.

Whole systems analysis is a practical tool for encouraging the fair distribution of costs and benefits of micro-generation projects, because it utilises widespread stakeholder participation in a process that enables accountability and transparency. Its disadvantages can include reproducibility of output and difficulty in reaching agreement because different views must be mutually resolved. However, the integrated whole systems methodology offers stakeholders a framework that guides and encourages constructive discussion, even in the midst of serious disagreements. Because the structure is iterative it allows participants to move away from obstructive topics and to revisit them at later stages in the process; to register conflicting views that cannot be resolved, and to set them beside issues where agreement, or compromise, can be achieved. The assessment can also be carried out sequentially at different times, allowing for cooling off periods, and can include new participants. Thus, its manner of deployment can be adapted to a range of situations and circumstances.

## V. STAKEHOLDER MAPPING

Thirty energy experts from a range of organisations attended a Stakeholder Mapping event held at Durham University in September 2010. Project aims were presented to stakeholders and questions drawn from a literature review and categorised under the three project areas (as described in Sec. III) were displayed on large posters as prompts for discussion. An open discussion around the research questions took place and stakeholders were encouraged to add views, issues, and references from grey and academic literature against each theme and question. This exercise aided methodology development by confirming our inclinations that the approach should be technology blind.

Next, a SWOT analysis was undertaken (Table I) to explore the multidimensional issues associated with micro-generation, to help identify desirable methodology attributes and highlight equity issues. Stakeholders placed comments and opinions onto a poster-scale SWOT diagram. The results of this exercise were mapped against the literature review and are summarised in Appendix A.

The SWOT analysis was used to inform the methodology and links between various factors. For example, final approval of the UK renewable heat incentive scheme is expected to remove some of the uncertainty related to policy and increase the demand for solar hot water and heat pump systems. Confirmation of the incentive in turn presents business opportunities, may reduce capital cost and generate revenue for the owner/operator.

TABLE I. Output from the SWOT analysis.

	POSITIVE	NEGATIVE
INTERNAL	<b>Strengths</b> <ul style="list-style-type: none"> <li>• Could enable benefits of the low carbon transition to be shared</li> <li>• Security of supply</li> <li>• Consumer empowerment</li> <li>• Increased awareness and sense of responsibility more generally</li> <li>• Inclusive - can bring communities together</li> <li>• Low risk compared to other mitigation options (CCS and Nuclear)</li> </ul>	<b>Weaknesses</b> <ul style="list-style-type: none"> <li>• Retrofit issues</li> <li>• Variability</li> <li>• Timescales for changes in policy and technology</li> <li>• Growth in micro-generation sector could be detrimental to other sectors</li> <li>• Capital cost</li> <li>• Technological maturity and credibility</li> <li>• Shortages of component parts/materials</li> <li>• Technology embodied energy/carbon</li> <li>• Lack of political support</li> <li>• Complex technology rather than simple</li> </ul>
EXTERNAL	<b>Opportunities</b> <ul style="list-style-type: none"> <li>• Development of new markets</li> <li>• Energy storage technology development</li> <li>• FiTs and other financial incentives</li> <li>• Potential to integrate energy citizenship and environmental citizenship through empowerment</li> <li>• Smart metering and monitoring of homes</li> <li>• Education opportunities for children and adults</li> </ul>	<b>Threats</b> <ul style="list-style-type: none"> <li>• Provides secure energy for some and not others</li> <li>• New nuclear build and CCS encourages centralized generation to be maintained</li> <li>• People don't like being told what to do. Other sectors trying to convey messages at same time—info overkill</li> <li>• Potential to enhance marginalization/exclusion and inequalities of wealth and power</li> <li>• Economic downturn</li> <li>• Poor technology performance</li> <li>• Distraction from other priorities, e.g., insulation, double glazing, air tightness</li> </ul>

Following the SWOT analysis, the stakeholders and project team listed desirable attributes for the methodology. The group agreed that it should be generic, versatile, and flexible enough to accommodate future and unknown variables. Other attributes include accessibility to users from all disciplines and the potential to be used iteratively and assist decision making. The group felt that target users of the methodology should be interdisciplinary teams (e.g., local authorities, housing associations, community groups, consultants) planning energy projects at community or group scale. The stakeholders also agreed that inputs to the methodology should be readily available and should avoid a numerical output to facilitate variable and unknown inputs and to attract a range of users.

The methodology was reviewed in the open forum of the mapping event. Stakeholders favoured a structure with equity and carbon reduction at its core, using theme entry points with



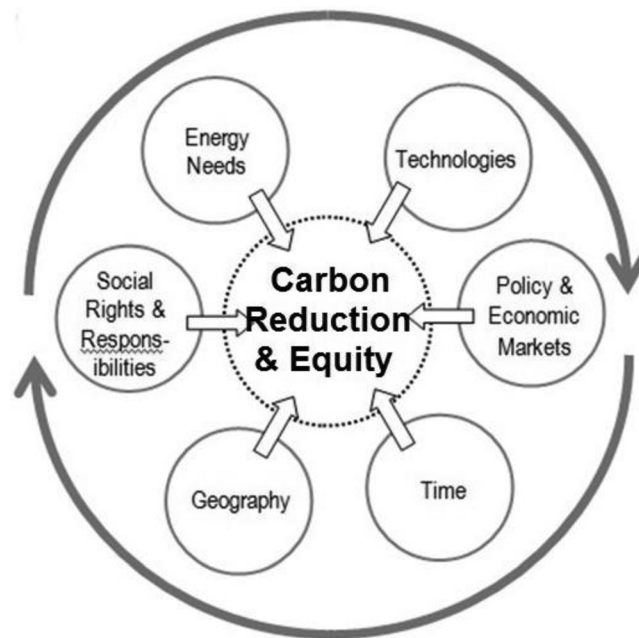


FIG. 2. Early stage methodology development.

accompanying checklists (Appendix B) to serve as prompts for discussion under each theme. Following the mapping event, checklists were developed for each entry point and circulated for revision and improvement. A set of six initial entry points were devised during the mapping event (Figure 2). Simulated, prescribed, case studies (as opposed to real case studies) were favoured by the group as a means for testing the methodology and to allow comparison between groups working on the same case study. The methodology is intended to work as a process whereby the checklists act as prompts for discussion under each theme. The themes can be discussed in any order and are revisited throughout the process (especially when links between themes have been uncovered). The output produced is in the form of notes, highlighting pertinent comments and identified links. Ten case studies were originally designed, the four eventually chosen were felt by the stakeholders to be representative of the main types of communities found within the UK and also reflected some of the areas of expertise of the stakeholders, e.g., case study 1 represents a rural village community that could have links with issues such as network infrastructure constraints or fuel poverty. Case study 2 allows for an exploration of empowerment or disempowerment of a tenant community managed by a RSL. The completed methodology (Figure 2) was circulated to stakeholders prior to testing using case studies.

## VI. STAKEHOLDER WORKSHOP

Four case study scenarios (Appendix C) were developed by the project team and stakeholders and used to test the methodology during a stakeholder workshop event (held February 2011) attended by around thirty energy experts.

The revised methodology, checklists for each entry point and the four case studies were sent to participants prior to the workshop. During the workshop attendees were split into two groups and given two case studies each to test during the day. Group feedback was given after each case study had been completed. To test the flexibility of the methodology participants also undertook sensitivity analysis where they changed one of the case study variables, this revealed some issues that are common to all of the case studies and issues that are variable (Table II).

### A. Refining the methodology

After testing, the ability of the methodology to meet its original objectives was evaluated by the workshop participants who agreed that the methodology provided a sound framework

TABLE II. Relevant issues from case study testing.

Common to all	Variable
Need for education	Income
Awareness raising	Age
Information provision	Housing condition
Supplier (technology and energy) impartiality	Benefit eligibility
Uncertainty over incentives	Home ownership
Future energy mix	Reliance on public transport
Government policy	Energy needs
Climate change	Resources available
	Technology

for considering the equity issues associated with the selection of micro-generation systems. It proved a useful tool in facilitating group consensus by providing a series of prompts to direct the users. This has particular value for decision makers working outside their field of expertise.

Revisions and improvements were made following stakeholder feedback. To improve the flexibility of the methodology and support the iterative approach (one iteration is represented by a complete sweep of all six themes) the group agreed that themes should be viewed sequentially through a lens as if using a microscope. Using this approach any single theme could be viewed under the subject of high definition focus while the other related themes provided background and context (Figure 3). A flow diagram summarising the steps taken to develop the methodology is shown in Figure 4.

## VII. APPLICATION OF THE METHODOLOGY

The utility of the methodology was tested firstly during the stakeholder workshop (as described in Sec. VII) using synthetic case studies and also using a real case study by engagement with a local community planning to erect a community owned wind generator and asking

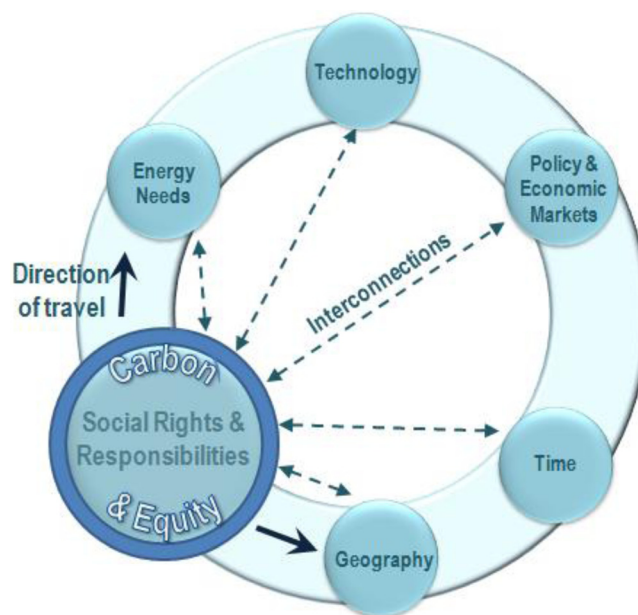


FIG. 3. Diagrammatic representation of the methodology following development and testing.

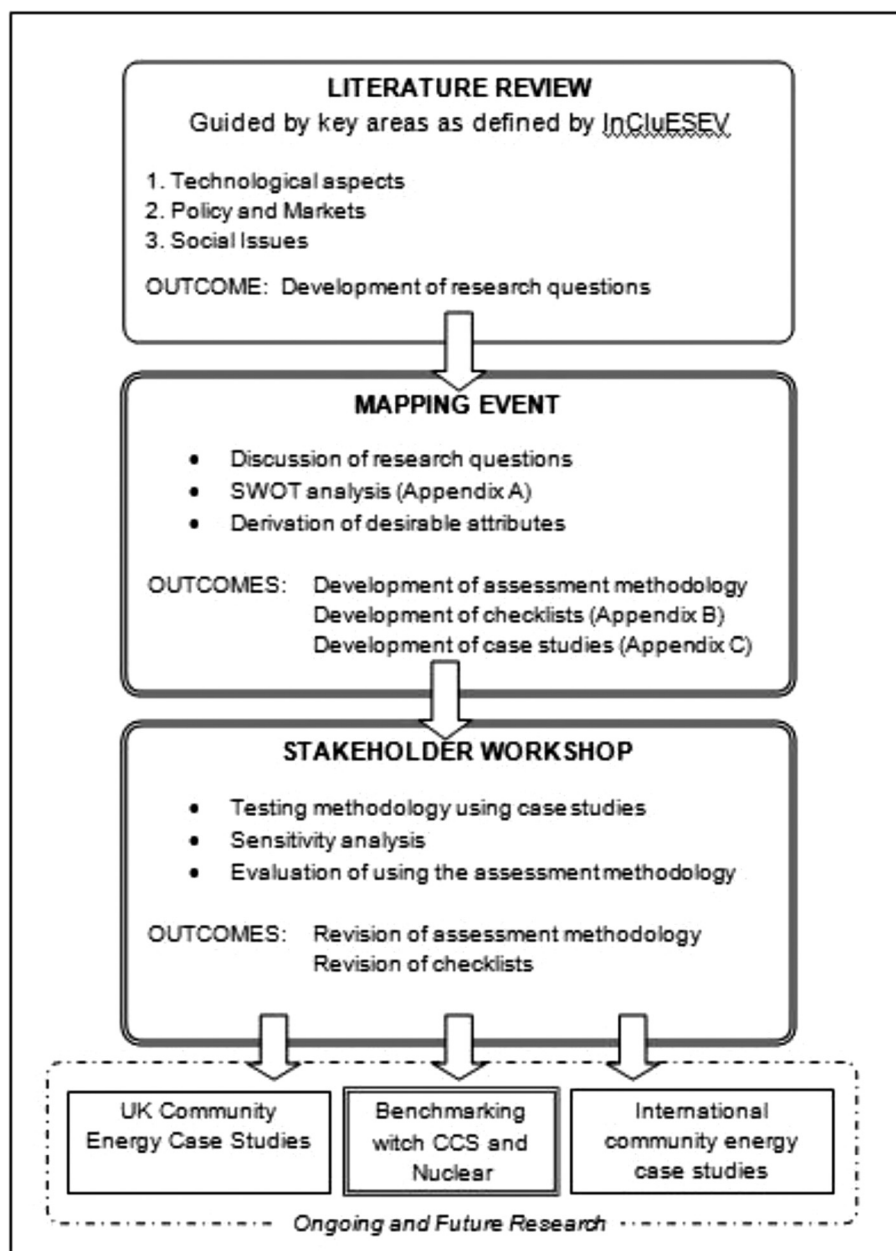


FIG. 4. Flow diagram summarising methodology development (Double outlined boxes represent tasks where the project team was assisted by stakeholders).

them to apply the methodology to their project. The community was chosen because of existing links with the project team and because the consultant involved in their feasibility study was also a project stakeholder and assisted in developing the methodology.

The number of English households included in case studies 1 to 4 was estimated by mapping them against English housing statistics (Table III) to determine the relative dominance of each case study group. The number of households in fuel poverty has also been included. England has  $21.5 \times 10^6$  households, 80% are located in urban areas (with a population exceeding 10 000) and 20% are located in rural areas (with a population not exceeding 10 000).<sup>40</sup> Urban and rural areas occupy 20% and 80% of the land area respectively. The majority of English homes are greater than five years old and are privately owned or mortgaged. RSLs and private landlords control 17% and 14% of English households, respectively.<sup>32</sup>

TABLE III. Number of households represented by the case studies.

Case study	Summary	No. of households (M)	% of Total
1	Rural, private	4.30	20
2	Suburban, RSL	2.8	14
3	Suburban, new build	Estimated 0.75	3
4	Suburban, private owned/landlord	13.6	63
	TOTAL	21.5	100
	Number in fuel poverty in England	3.44	16

### A. Case study 1: Rural communities

Issues affecting rural communities include age of housing stock, access to mains gas, being on the extremities of the electrical network and land designations that could constrain system choice (although space may favour larger scale renewable generation). Incentives designed to make energy efficiency improvements to housing stock and promote energy efficient practices are essential before micro-generation is considered. Equity issues for rural communities include restricted fuel choices for elderly residents who may have to rely upon costly electric heating. Policy measures targeting high emitters would be inequitable for these communities, because housing stock condition and rural location means that inhabitants are likely to have above average energy demands.

### B. Case study 2: Urban communities managed by a RSL

RSLs control around 17% of UK housing stock<sup>33</sup> and have bulk buying/bargaining power. RSLs also have the opportunity to promote energy literacy and appropriate technologies via regular surgeries and mailings to tenants and to gather energy performance data. New-build and major refurbishment projects offer opportunities for the incorporation of micro-generation and the RSL could benefit from capital funding. The RSL needs adequate information and guidance to make good technology choices and consider the future consequences of those choices. The integrated whole systems methodology developed from this research could meet these criteria and has value in this role.

Equity issues associated with this case study include tenants being involved where possible in energy-related decision making to prevent them feeling vulnerable and marginalised, especially if lifestyle changes are required to operate newly installed technology. Tenants may not have energy as a key concern, many will be low income households with their priorities set on providing for themselves. There is potential for these people to become decoupled from their own use of energy if ultimately set rates for energy services are charged in future.

### C. Case study 3

Case study 3 is a future scenario looking forward to 2021 when newly built homes will have been carbon neutral for 5 years. Using current build rates, Table III estimates that 0.75 million houses would be less than 5 years old and would have some form of installed micro-generation (assuming micro-generation is the route chosen by developers to meet the 2016 target). Research shows that purchasers of low or zero carbon homes have been motivated to do so because they have green values and want low energy costs,<sup>27</sup> the installed technology may be viewed as a status symbol. During the workshop, stakeholders reported cases where homeowners have installed micro-generation to offset more profligate activities (long haul travel, car ownership),<sup>34</sup> or use more energy at home because they are producing it from a low carbon source<sup>35</sup> and cases where customers have installed PV systems and reduced their overall energy demand.<sup>36</sup>

Householders in this case study will benefit from FiTs, grants, buy-back agreements and will have the opportunity for reduced imported energy demand. The behaviour of the occupants

is more likely to affect energy demand than building fabric. The success of such zero carbon new build developments at reducing carbon relies upon users being conversant with the use of the installed technology and making any lifestyle changes required to optimise its performance. Equity issues affecting case study 3 include the effects of installing additional or replacement micro-generation technology or charging electric cars upon neighbouring households and issues of who should pay for any required upgrades of the electrical network.

#### D. Case study 4—Urban communities

The dominance of this type of community throughout the UK offers big opportunities to influence, regulate, and incentivise individuals; but the mix of tenure, age and condition of the housing stock and varying energy needs of occupants present many challenges that could best be assessed on a case by case basis. The proposed “Green Deal”<sup>37</sup> which proposes to fund energy improvements from annual savings advocates this approach and could be well suited to these communities because those with the most inefficient homes have the most to gain. Success will depend upon the practicalities of making the required improvements. This case study strengthens the need for engagement with social and private landlords. Around 680 000 homes across the private rented sector are classed as very energy inefficient. The UK government plans to address this by preventing private landlords from renting homes with the lowest energy rating (F and G) from 2018. Landlords will be able to finance refurbishments using the “Green Deal.”

Around 16% of households in England are classed as being in fuel poverty (i.e., spending more than 10% of their household income on fuel). This number is expected to increase with predicted increases in domestic energy bills. Walker and Cass<sup>38</sup> have estimated that every 1% rise in energy price correlates to 40 000 additional households becoming fuel poor. Walker,<sup>28</sup> stated that a significant number of people who have low incomes and are at risk of being in fuel poverty are not homeowners (around 18% of households are in private rented accommodation) and are in fuel poverty (this represents one fifth of the total number of households in fuel poverty). Households in rural areas are more likely to be in fuel poverty than those in urban areas 18% and 12%, respectively. However more people live in urban areas. Using figures from Table III and assuming 2.3 people per household<sup>39</sup> these percentages equate to around 2 million urban households experiencing fuel poverty compared to  $0.77 \times 10^6$  rural households.

#### E. Case study 5

Case study 5 represents a rural village comprising 215 homes and apart from the fact that the village has access to mains gas, there are some similarities with case study 1. The community intends to erect a single 500 kW wind turbine that will generate income for community facilities. A community association has been established and a feasibility study has been undertaken that suggested a wind turbine as the most suitable option for the village. The community association are in the process of obtaining planning approval and are investigating options for financing the project. Project development funds have enabled members of the local community to train as energy auditors, sixty energy audits have been undertaken within the community and some people have been given energy monitors. The intention is that a portion of the income generated from the turbine will be used to improve insulation standards of homes in the village.

The project team attended a community consultation event at which the results of the feasibility study were discussed among the wider community and local opinion was canvassed. Following this event, six members of the community association agreed to apply the methodology to their project at a separate workshop hosted by the project team. Following a short presentation relating to its use, the community members worked in two groups of three and used the checklists to prompt discussions around each theme within the methodology while noting key discussion points. At the end of the session, they were provided with a questionnaire that allowed them to comment on their experience of using the methodology, the equity issues raised during this exercise are discussed in the following section.



In terms of the usefulness of the methodology, all committee members stated that the exercise had been useful for them because it highlighted gaps in knowledge amongst community members, made them think about issues they had not considered before and provoked discussion about wider national and international policy and equity issues that linked back to their proposed project. The community also suggested ways in which the experience of using the methodology could be improved, this included making the language less technical and also having someone facilitate the discussion so that the community had a point of reference for asking questions about particular aspects and also to prevent individuals from dominating the discussion.

Members of the community association are relatively affluent retired professionals and, prior to undertaking energy audits, were not really aware of the incidence of fuel poverty within their own village and were surprised at the difficulties they encountered when trying to engage with their local community and in particular elderly residents many of whom did not welcome engagement. Using the methodology in discussion with the community association drove use to ask different questions and uncovered some hidden equity issues.

Local issues were highlighted when members of the community association dealing with different aspects of the project used the methodology and got chance to link these different aspects, e.g., people who had been carrying out energy audits highlighted a lack of trust amongst elderly members of the community who did not want to accept help to improve insulation even when offered at no cost. Other members noted that some local people had developed suspicion of the community association with respect to what both they and the owner of the land planned for the turbine installation would gain from the project, i.e., if community members become shareholders what happens to their investment and who else could benefit from their investment. This caused the community association members to question whether they had done all they could to engage and raise awareness amongst their local community.

Wider issues raised included a discussion about national policy relating to FiTs and how and who funds this. The community felt that if they in part subsidise FiTs they should benefit from them and stated that if they did not take this opportunity then a developer could and would not necessarily share the financial benefits with the community. This discussion also highlighted feelings of inequity between developers and community groups where both have to pass through the same process when developing a project; however, the community group may be doing this on a smaller scale and with less expertise. There was also a feeling that when negotiating electricity buy-back, energy supply companies are less keen on community owned wind turbines and also feelings of disempowerment whereby community groups have little influence over local or national energy policy.

Equity issues raised related to technical aspects of the project highlighted some of the risks the community association may have to bear. The community association have planned to use some of the income generated by the planned turbine for its replacement at the end of its life, however they had not considered issues such as the possible need for replacement before end of life, e.g., by damage due to extreme weather or costs that may be included in decommissioning. When the community association enquired as to the cost for connecting the wind turbine to the electrical network, the quotation they received was three times the quotation received by the consultant who undertook the feasibility study leaving them frustrated that they had originally worried about high connection costs. The community association also has to take the risk of starting to build the turbine before FiTs are agreed. The time between start of works and final commissioning could be up to one year, during that time the FiT structure may have changed and could adversely affect revenue generation. A larger wind developer who is likely to have several projects in progression can more easily bear extra costs at one development as they may be offset by another development i.e. their risk is less concentrated than in the community case.

## VIII. EQUITY ISSUES

Using the methodology for the case studies above prompted the users to consider and discuss a breadth of equity issues associated with micro and small-scale generation projects



including issues they had not previously considered. This process can draw out unforeseen equity issues relating to freedom of choice, education, constraints that may limit opportunity and economic status. People can choose to reduce energy demand but lack of awareness and education may preclude this.

Tenants of privately rented accommodation on low incomes, ineligible for benefits generally have least equity because they have little control over their housing stock and energy supply. They may be in fuel poverty and struggle to reduce their energy bills. Private landlords are not currently legally obliged to provide housing that meets basic comfort levels with low running costs.<sup>40</sup>

Geographical location can affect equity, in rural areas people may be charged for upgrades to the electrical network required to support their planned micro-generation system. Land designations may constrain the type of micro or small-scale generation that is permitted.

The age, condition, and aspect of housing stock all have equity implications. The building fabric or the type of heating system installed can create high energy demands (regardless of the behaviour of occupants) and offer few opportunities for improvement. Policy measures targeting high energy users (e.g., personal carbon allowances) would be inequitable for people living in inefficient housing stock and could exacerbate fuel poverty.<sup>41</sup>

Climate change policies subsidised by the tax payer (e.g., the UK's Warm Front and the proposed Green Deal) may be more equitable than measures funded by gas and electricity consumers (e.g., EU Emissions Trading Scheme and FiTs),<sup>42</sup> when considering those on lower incomes who pay less tax.

The age of occupants also has an equity dimension. The elderly generally have higher hours of home occupancy and may be unable to handle solid fuels and rely upon more convenient yet expensive fuels (e.g., LPG, oil or electricity). Winter fuel payments for the elderly may be insufficient as energy prices rise. Leenheer *et al.*<sup>43</sup> found that age may be a factor governing the intention to save energy or install micro-generation.

Case study 5 demonstrates how direct public engagement at local level is important to provide consumers with independent, clear information as to the benefits of using micro-generation to allow them to build trusting relationships with community energy groups and installers. Micro-generation policy has focused upon increasing system uptake rather than on promoting behavioural change<sup>22</sup> and the connection between personal behaviour and energy consumption is lacking, i.e., fit and forget with no behavioural change as discussed by Bergman *et al.*<sup>44</sup> This is a major oversight because carbon savings will not be realised if the user is not aware how best to operate the installed technology and how best to use the energy produced.

Micro and small-scale generation technology is often perceived as a luxury of the affluent that is subsidised by the less affluent. Between 4% and 10% of the average gas and electricity bill respectively is allocated to environmental costs.<sup>45</sup> This includes funding for energy efficiency initiatives, carbon reduction programmes and emissions trading in addition to the FIT. Consumers thus pay a small percentage towards FiTs. The little available research suggests that early adopters are higher income, professional/managerial groups<sup>46,47</sup> less concerned with cost and more driven by issues of technology, environment, and self sufficiency.<sup>44</sup> Early adopters help to reduce local carbon emissions for everyone's benefit while growing the market for micro-generation and demonstrating the technology.

## IX. RECOMMENDATIONS FOR ENERGY POLICY

Using the integrated whole systems methodology for assessing the equity aspects of each case study and linking the results with housing statistics and UK energy policy has enabled the following recommendations to be made.

Application of the methodology to case studies 1 and 4 has highlighted that policy measures penalising high emitters decrease equity for inhabitants of older "hard to treat" housing stock and could push more households into fuel poverty. Policy measures that regulate private landlords and set standards (with respect to energy performance) for the type of accommodation

they can legally rent could offer some of the biggest improvements in energy equity for households in England.

Case study 5 shows that energy generation can offer communities a route to becoming more self-sustaining. Policy measures could be used to support community groups when planning energy projects because they currently have to buy-in expertise and develop reliance upon and trust in that expertise while investing large amounts of personal time, in the project. They often also have to maintain a high level of tenacity when negotiating barriers such as planning legislation, landowner agreements, environmental constraints (e.g., wildlife and aquatic surveys), community opposition, and connection issues. Policies that incentivise energy supply companies and project developers to work with communities could offer valuable support to these groups and help empower communities to develop energy projects for their local benefit. Supplier and developer obligations could also be used (e.g., by supporting local insulation or micro-generation initiatives) to ensure that local communities gain some benefit from generation projects within their area even if they are not directly involved in the project.

Case study 4 represents a large proportion of English households and highlights the fact that fuel poverty measures should be aimed primarily towards urban areas which have a higher incidence of fuel poverty. Although there may be more older people living in rural communities that may be vulnerable to fuel poverty, the UK winter fuel allowance should help counteract extra fuel costs. Measures directed toward urban areas should concentrate upon improvements to building fabric before considering the installation of micro-generation, this has also been demonstrated by the village in case study 5. Micro-generation strategy should be targeted towards reducing carbon dioxide emissions from urban/suburban areas which may be harder to treat than rural areas that are often more suitable (where land designations permit) for large scale generation for example wind farms and biomass district heating.

Although there are many technical constraints associated with specifying micro and small-scale generation (including the orientation, nature, condition, and construction of building fabric) and assuming capital costs can be overcome, generally the most suitable types of distributed generation for urban communities (such as those encompassed by case study 4) experiencing fuel poverty (assuming the majority of systems would be retrofitted) are of micro scale and include solar hot water, photo voltaics, micro-combined heat and power and air source heat pumps. Given that main gas is likely to be available to an urban community, micro-combined heat and power could be more suitable than heat pumps as the over production of heat associated with these systems could complement hard to treat, poorly insulated properties.

Policy measures funded by the tax payer are likely to be more equitable than those funded by consumers because those on lower incomes pay less tax. Energy finance schemes such as The Green Deal could improve equity for the households considered in all the case studies. A better understanding of how best to persuade consumers of energy to adopt more energy conscious lifestyles is required. This could be achieved by training, education, and awareness raising so that eventually energy conscious behaviour becomes the norm.

## X. CONCLUSIONS

The InCluESEV network has developed an integrated whole systems methodology that provides a useful tool for assessing the equity aspects of micro-generation uptake. The tool uses an iterative approach and is suitable for interdisciplinary, group, or community scale energy projects. It has been tested using imagined and real case studies. The methodology is novel in the fact that it focuses on equity while considering energy generation projects, has been developed by a very wide range of multidisciplinary energy stakeholders, and also in the steps taken during its development. The fact that it offers a comprehensive analysis technique that forces the user to consider a breadth of issues relating to micro or small-scale generation projects and helps to draw out potentially unforeseen issues at an early stage (for example, future arrangements for technology replacement, energy provision and future income) is a further benefit.

This methodology has uses for a wide range of groups including housing associations, local government, planners, community groups, consultants, technology suppliers and developers. This research is being extended to include further testing, using real situations and international case studies. The methodology has also been used for assessing other low carbon technology options such as gas or coal fired generation combined with carbon capture and storage and nuclear power. The ultimate aim is to extend the application of the methodology for benchmarking the equity issues relating to the use of micro-generation systems compared to other low carbon technology options.

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## APPENDIX A: DETAILED INFORMATION FROM SWOT ANALYSIS

### 1. Strengths and opportunities

Strengths of micro-generation include energy security and economic and environmental benefits that can be realised relatively quickly through existing delivery chains<sup>23</sup> and the potential for business to develop new market models. Further strengths include reduced energy losses as less energy flows through the entire electricity network. Around 65% of primary energy input is lost (mainly as wasted heat) in the electricity supply system.<sup>24</sup>

Opportunities provided by micro-generation include business diversification and the creation of new markets and skills sets. Micro-generation offers communities a tangible link between energy supply and demand and offers them more control over their energy arrangements whilst benefitting from economic rewards. Community energy projects also offer opportunities for awareness raising, education, and promoting environmental citizenship.<sup>25</sup> Other social benefits include feelings of well-being and improved numeracy and literacy skills associated with recording and monitoring energy information.<sup>26</sup> Other opportunities provided by micro-generation uptake include the potential for increased carbon reductions through the double dividend effect<sup>27</sup> where the consumer places a higher value on the energy produced by installed micro-generation and in addition to producing energy from a low carbon source they also reduce consumption. Micro-generation can help to alleviate fuel poverty where social landlords have incorporated it and borne the capital cost of its installation.<sup>28</sup>

### 2. Weaknesses and threats

Stakeholders perceived the weaknesses of micro-generation technology as its variability, difficulty of retrofit, planning constraints, economies of scale and concerns about future availability of resources and component parts. Threats were listed as uncertainty relating to future policy and tariffs (e.g., the recently decreased FiTs) and political support for other low carbon energy systems that support dominance of centralised generation (e.g., nuclear). Technology credibility and immaturity,<sup>29,30</sup> mixed messages and lack of clear impartial advice relating to technology choice, embodied energy and lifespan of micro-generation technology<sup>22,31</sup> and concerns over safety during their installation and operation were also recorded as threats. The stakeholder group also felt that micro-generation could enhance marginalization by exclusion creating inequalities of wealth and power.

**APPENDIX B: CHECKLISTS TO ACCOMPANY THE METHODOLOGY****Energy needs (EN)**

1. Energy use/routines/lifestyles
2. Energy demand
3. Security and continuity of supply
4. Affordability
5. Demand side management - customer flexibility (when, how much, fuel source)
6. Comfort levels
7. Public awareness and communication
8. Employment opportunities for micro-generation installers, local installers and opportunities for maintenance
9. Perceived effects of micro-generation on property value
10. Empowerment from communities or individuals taking more control of their energy use and provision
11. Rebound effect and opposite effect from increased consumer control

**Social rights and responsibilities (SRR)**

1. Local share schemes—all benefit from FiTs
2. Alleviation of fuel poverty and societal responsibilities to that end
3. Desire and knowledge to reduce energy demand and use micro-generation
4. Empowerment by increased control of energy
5. Information on billing, energy efficiency, technologies
6. Addressing energy efficiency before incorporating micro-generation
7. Equality of access to micro-generation
8. Education of the younger generation “pester power”
9. Fair trade labelling of green energy
10. Employment opportunities for micro-generation installers
11. Safety issues of installing
12. Tenancy agreements to encourage responsible use of energy
13. Conflicts between consumerism and reducing energy use.
14. Who pays to contribute to CO<sub>2</sub> reduction
15. International responsibilities – materials, workforce, offshore emissions, effects of climate change

**Technologies (TECH)**

1. Embodied carbon
2. Gaps/performance limitations
3. Equitable resources for source materials
4. Device lifetime end of life recycling or disposal
5. Energy yield and offset use of other resources
6. Power quality from increased micro-generation
7. Network capacity and flexibility
8. Energy efficiency then micro-generation
9. Demand side management
10. Appropriateness of scale and technology choice
11. Appropriateness of hybrid solutions
12. Grid connected or autonomous
13. Link to transport/electric vehicles

14. Negative consequences—micro-generation vs. adjacent large scale wind appropriateness of solution

### **Policy and economic markets (PEM)**

1. FiTs as drivers for markets rather than carbon benefits/appropriateness
2. Building control—new build to incorporate micro-generation
3. Energy efficiency incentives, grants, and FiTs
4. Suppliers need to make money balanced against energy efficiency/reducing CO<sub>2</sub>
5. Rewarding those who use less energy
6. CO<sub>2</sub> reduction targets—effects upon businesses who struggle to meet targets, is micro-generation a solution?
7. Should suppliers pay for the low carbon transition or should we all be taxed?
8. Market driven vs. subsidized micro-generation
9. Planning policy may deter installation of micro-generation
10. Carbon cost
11. Carbon targets not being met
12. Tension between economic rewards and benefits of using micro-generation
13. Miss-selling, impartiality, overstated performance
14. Disaggregated nature of UK energy supplies
15. Smart meter roll out
16. New nuclear build and carbon capture and storage policy support and impacts upon micro-generation uptake
17. Micro-generation as a transition technology or long lasting solution

### **Time (TIME)**

1. In an all electric future
2. In a future with increased reliance on imported gas
3. In a future with greater dependence upon intermittent micro-generation
4. In a future with little micro-generation
5. New technologies
6. Comfort, security and resilience varying with time
7. Lifetime/disposal
8. Micro-generation is a stop gap or long term solution
9. Life after FiTs and other subsidies
10. Cultural and demographic and population changes
11. Climate change
12. Changes in efficiency, cost, yield—improvements

### **Geography (GEOG)**

1. Ambient climate—warmer or colder, wetter, or windier climates
2. Daylight hours
3. Energy sources available—energy mix
4. Network capacity
5. Differing energy policies
6. Workers conditions, pay, resource exploitation, effects of climate change
7. North/South implications for micro-generation—transportation and distribution of energy/energy yield, e.g., PV in the S, energy density in centres of population
8. Rural, suburban, urban, island
9. Micro-generation built into new energy infrastructure rather than retrofit—developing/industrializing nations

**APPENDIX C: ADDITIONAL INFORMATION RELATING TO CASE STUDIES 1 TO 4**

TABLE IV. Summary of case studies.

	Case study 1	Case study 2	Case study 3 future scenario	Case study 4
Location	Rural village	Urban block of flats	Urban estate of similar new build properties	Urban mixed age and types of housing
Access to gas	No	Yes	Yes	Yes
Fuel poor	Yes and No	No	No	Yes
Ownership	Owner occupier, mortgaged, tenanted	Registered social landlord	Owner occupier, mortgaged	Registered social landlord, private landlord, owner occupier
Housing stock	Mixed existing	Identical	New	1950 s semi
Micro-gen Mode	Retrofit	New build, integrated	New build integrated	Retrofit
Disposable income	Some	Low	Medium	Low
Occupiers	Mixed	Mainly families	Young couples, families	Mixed families, elderly
Energy demand	Above average	Average	Average	Above average
Occupancy	Mixed	Mixed	Evenings/weekends	Mixed
Drivers for low carbon life	Improved comfort, reduced energy bills	Reduced energy bills, good comfort levels	Reduced bills, green interest, income source	Improved comfort, reduced energy bills.
Technology choice	Yes	No	Yes	No
Issues	Restricted fuel choice, limitations of housing stock, fuel poverty, planning policy	Low income, age, unemployment, fuel poverty	Occupants affect energy demand, income generation, carbon offsetting, display green values	Fuel poverty, unemployment, housing stock condition and space may affect micro-gen choice.
Future	Could be one of first areas to be all electric	Employment opportunities for community, technology replacement issues	Future scenario looking ahead to 2021	Increased fuel poverty, smart metering and incentives could benefit these people
Opportunities for adjacent large scale generation	Yes—space and resources suitable	No—space constraints	No—space constraints	No—space constraints

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